BPIE | BUILDINGS PERFORMANCE INSTITUTE EUROPE

i2 4C INDUSTRIAL INNOVATION FOR COMPETITIVENESS

BUILDING AUTOMATION AND CONTROL TECHNOLOGIES

Deep-dive #4

SUMMARY

Building Automation (BA) can refer to Building Automated Control Systems (BACS), Building Automation Technologies (BAT) as well as Home and Building Energy Management Systems (HEMS/BEMS) solutions.[1]

Nowadays, these technologies mainly focus on HVAC systems and can be applied in varying degrees of integration and sophistication. Three main areas of transition can be identified in these different systems: model-based controls[2], semantic tagging[3] and smart building applications. All these changes focus on dynamic or even self-learning control systems. With the "Internet of Things", the market will move to the "Ubiquitous Home" – where sophisticated systems study user behaviour/lifestyle and respond accordingly.

In 2013, the BA market was worth more than $20 billion and it has now reached a critical mass from where it seems set to break through to the mass-market. Yet today, BA systems are not used to their full potential to lower energy consumption in buildings. Maximising this potential could provide a large opportunity for the construction value chain to significantly lower building operation costs and create new jobs for the energy management of buildings. The innovation potential to achieve a full market implementation lies in solutions for the following issues:

- Organisational and service innovation;
- Product innovation for existing buildings;
- Marketing innovation.

BA is cost-effective for essentially all commercial buildings, regardless of national energy prices, usage and climatic factors, provided it is correctly installed, commissioned and operated. The average net energy savings per installation are about 37% for space heating, water heating and cooling/ventilation, and 25% for lighting. Currently only about 25% of commercial buildings have properly installed BA.

Innovations on different segments of the construction value chain reinforce each other, creating a positive feedback loop: BA is a complement to smart meters and is crucial in the roll-out of the buildings interaction with the energy market (i.e. energy production, storage and demand response).

The contributions towards climate change mitigation are even more significant. A reduction of 260 to 419 million tons of CO_2 would reduce Europe's emissions from fuel combustion of 8-13% by 2035.

Innovation in the Building Automation sector is strongly linked to innovation and change in the IT and energy sectors. These sectors will strongly impact the technology evolutions of BA. The US and Japan have strong BA markets, but most product developments for the European market will occur within Europe, although many components may be sourced from outside.

[1] In this document, the general terminology Building Automation (BA) is mostly used.

[2] Model-based controls are automated building-control software predicting the necessary behavior of a building based on the predicted occupancy, weather forecast, etc. They look further ahead and adapt the building systems in anticipation to the forecast.

[3] Semantic tagging is the labelling of all components in an entire building's technical system. Naming all these components allows them to be integrated in a system and communicate with each other.

The building automation and control industry is quite fragmented with many players involved, even though the top six companies account for about 37% of the installed system sales. Because these conventional actors operate on closed source software and systems, more small players enter the market, offering simple open-source HEMS. This allows their products to be implemented more easily in bigger buildings. Some large new actors like Google NEST and Apple are entering the market as well, focusing on the home-side of it and less on complex building systems. They often have innovative open-source platforms, allowing different applications to run.

TO CREATE A VIRTUOUS CIRCLE, BUILD CONFIDENCE AND DRIVE DEMAND OF BA, THERE IS A NEED TO INCREASE BOTH RELIABILITY ON THE ENERGY SAVINGS AND ADAPTATION OF BA. THIS BY IMPLEMENTING THE FOLLOWING MEASURES:

- **Educating and improving the supply chain skills – focusing on energy engineers or maintenance companies who will operate the systems, on HVAC engineers and installers as well as on building owners.**
- **Strengthening interoperability between different building installations like heating, ventilation units, chillers etc., and a standardisation of their communication protocol.**
- **Supporting and promoting (further) uptake of smart grids, demand-side management and on-site renewable energy production.**
- **Raise awareness in the market of the value proposition.**
- **Push the implementation of ISO 50001 (energy-management-system standard) in the building sector, which has the potential to stimulate the integration of energy-saving control systems.**

This focus paper on 'BUILDING AUTOMATION AND CONTROL TECHNOLOGIES' is part of a larger report looking into innovation within the construction value chain. The report and three other papers are available on BPIE and i24c's websites. www.bpie.eu and www.i2-4c.eu

ONGOING TRANSITION

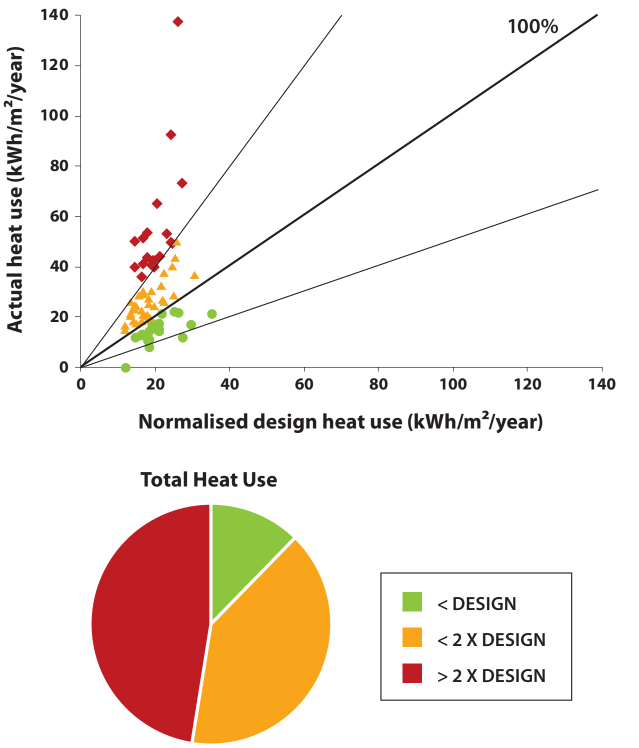
Building Automation (BA) can refer to Building Automated Control Systems (BACS), Building Automation Technologies (BAT) as well as Home and Building Energy Management Systems (HEMS/BEMS) solutions.[4] Today these technologies mainly focus on HVAC systems and they can be applied in varying degrees of integration and sophistication. Detailed analyses have shown that BEMS are among the set of cost-optimal measures that will produce economically viable energy savings.

Three main areas of transition can be identified in these different systems:

- Model-based controls[5];
- Semantic tagging[6];
- Smart building applications.

All of these changes focus on dynamic or even self-learning control systems. Instead of static, predefined parameters for control, the system itself can define and steer the relevant parameters (e.g. optimal temperature, heating time, light lumen, operational-time installations, overheating protection), in a specific moment, and based on occupation, (predicted) inside- and outside temperature and so on. The final energy use in a building is generated through a combination of building envelope characteristics (incl. design and orientation), installations (incl. renewable energy) and user behaviour.

Figure 1: Monitoring designed and actual heat use in dwellings (Source: Ghent University)

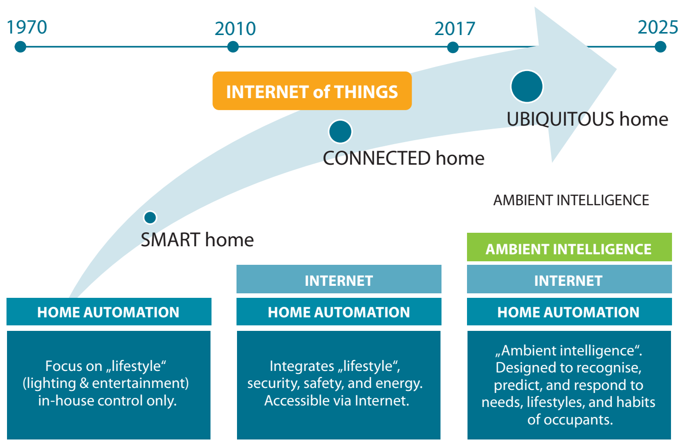


After finalising construction or renovation, the behaviour is adjusted to achieve the expected end-functions of buildings, e.g. turning on the heating/thermostat when cold, opening the windows for ventilation, turning on the air-conditioning if too warm, switching on the lights, etc. Very often, this behaviour leads to the calculated final energy demand (i.e. the building envelope and the installations) and the real measured final energy demand being very different.

Figure 1 clearly shows the difference between the actual and the designed heat use for space and domestic hot water heating of low-energy dwellings and the effect of user behaviour on the final energy demand. One quarter of the dwellings (with highest heat use over design) are responsible for almost 50% of the heat use of the site.

With the ongoing transition towards the "Internet of Things" (figure 2), the market will move to the "Ubiquitous Home"– where sophisticated systems learn user behaviour/lifestyle and respond accordingly.

Figure 2: Evolution of connected and smart homes (Source: BSRIA)



"If we can combine model-predictive control together with self-learning smart applications, then we are almost there." Siemens

"Between 20-30% of the installed systems could be largely improved if they would be combined and people would invest in this combination. Although it's known technology, nothing new, no model prediction, no nothing. It's just a combination of different signals." Siemens

[4] In this document the general terminology Building Automation (BA) is mostly used.

[5] Model-based controls are automated building controls, predicting the necessary behaviour of a building based on the foreseen occupancy, the weather forecast, etc. They look further ahead and adapt the building systems in anticipation of the forecast.

[6] Semantic tagging is the labelling of all components in an entire building's technical system. Naming all these components allows them to be integrated in a system and communicate with each other.

INNOVATION POTENTIAL

Figure 3: Outlining the innovation of 'Building automation and control technologies' (Source: BPIE)

BARRIERS

- Too often conventional building automation systems with **fixed and predefined settings**
- Systems are often **not designed or operated to their full potential or wrongly installed** or used
- Limited market availability of systems to be **integrated in existing buildings**
- **Conventional actors** operate on closed source software and systems

DRIVERS

- Evolution to **model-based controls** applying software predicting the behaviour of a building
- **Semantic tagging**, i.e. the labelling of all components in an entire building's technical system
- Transition towards **Internet of Things and ubiquitous homes**
- New players entering the market, offering simple **open-source platforms**

INNOVATIVE SOLUTIONS

- **Organisational and service innovation** overcoming the mismatch between the construction sector and building automation to optimise the energy consumption with dynamic and self-learning control systems
- Product innovative solutions integrating **building automation in existing buildings**
- **Marketing innovation to raise awareness** among architects, installers and end users on energy-saving potential and other benefits such as safety and comfort

In 2013, the BA market was worth more than $20 billion and it has now reached a critical mass from where it seems set to break through to mass market. Yet today BA systems are not yet being used to their full potential to lower energy consumption in buildings. Maximising this potential could provide a large opportunity for the construction value chain to significantly lower building operation costs and to create new jobs for the energy management of buildings.

The innovation potential to achieve full market implementation lies in solutions for the following issues:

- Organisational and service innovation. Overcoming the mismatch between the inertia of the construction sector and the complexity of BA systems. A different way of designing a building's HVAC system is required, where it should be considered from the design stage that a balance between energy efficiency and operation efficiency is needed. There is no use in advanced systems if they are not designed or operated to their full potential or if they are wrongly installed or used. All the new BA systems available on the market or under development could easily be used to save energy in buildings by optimising energy use, but are very often not used for that purpose (they are more commonly used to monitor system breakdown or malfunction or to measure energy use).

  The market should transform more strongly from the conventional fixed, predefined settings to self-learning and/or -steering systems that regulate buildings in a dynamic way. Manufacturers have to skill up installers, energy experts and ICT personnel to achieve the necessary competence levels to correctly design, install and operate systems.

- Product innovation for existing buildings: more complex systems are mostly developed from a new buildings perspective, and they are often very difficult to implement in existing buildings. There are integrated systems for existing buildings, but market availability is limited.

- Marketing innovation: the largest growth potential lies in marketing innovation to raise awareness among architects, installers and end users on the energy-saving potential and other advantages, such as safety[7] and comfort. Both government organisations and manufacturers of BA have an important role in this process.

[7] In the US, 90% of consumers indicate security as one of the top reasons to purchase a smart home system.

VALUE TO CAPTURE

BA is cost-effective for essentially all service-sector buildings, regardless of national energy prices, usage and climatic factors, provided it is correctly installed, commissioned and operated. The average net energy savings per installation are about 37% for space heating, water heating and cooling/ventilation, and 25% for lighting. Currently only about 25% of service-sector buildings have properly installed BA.

Proper installation[8] and operation of the better types of BA in households will on average save 30% of heating and hot water energy compared to the average default control systems installed in the building stock.

Innovations on different segments of the construction value chain reinforce each other, creating a positive feedback loop: BA is a complement to smart meters and is crucial in the roll-out of the buildings interaction with the energy market (i.e. energy production, storage and demand response).

The Copper Alliance Institute claims that BA has a potential of saving 15-22% of the total energy consumption in European buildings. It is highly cost-effective, with benefits being nine times higher than costs. Even more significant are the contributions towards climate change mitigation. A reduction of 260 to 419 million tons of CO_2 would reduce Europe's emissions from fuel combustion of 8-13% by 2035.

Two scenarios are generally presented to capture added value from the BA perspective:

- The optimal scenario: based on a perfectly functioning construction-market scenario, where all cost-effective energy-saving opportunities are seized, without serious constraints to effective service delivery.
- The recommended scenario: a more realistic depiction of the potential to deliver additional savings beyond the business-as-usual.

A rough estimation of the possible economic and environmental value potential for both scenarios is listed in table 1.

In Europe, mainly Germany, Scandinavian countries, the UK and The Netherlands are leading in implementing BA.

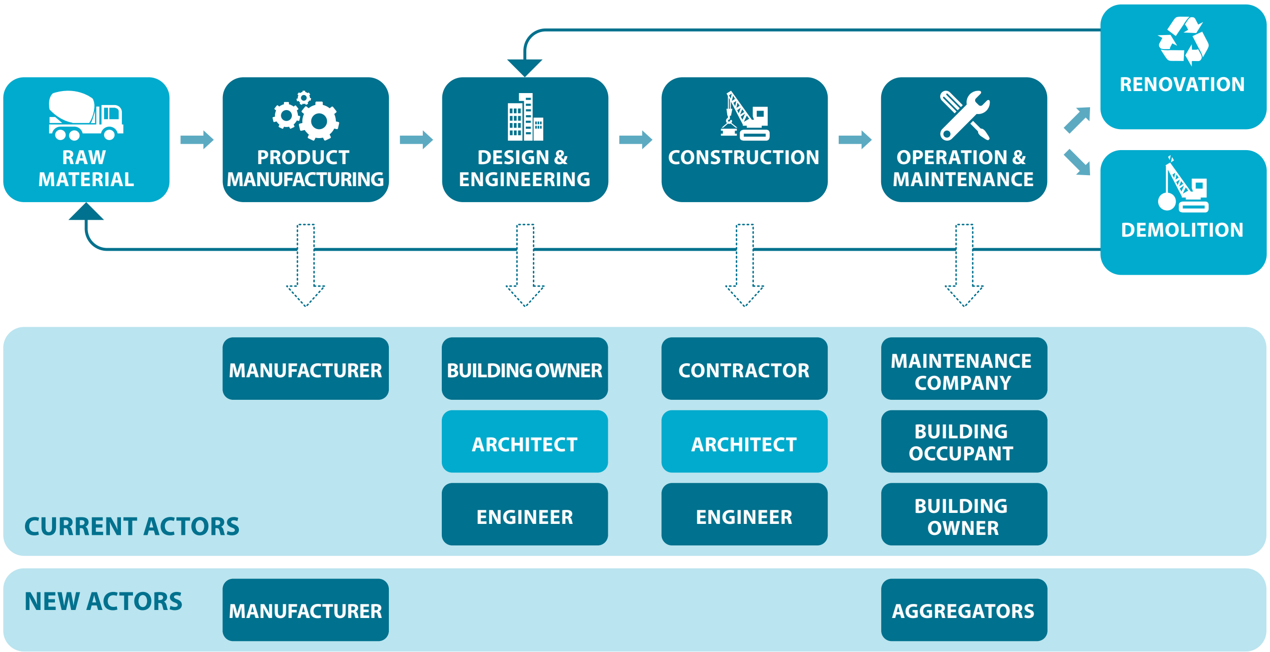
Table 1: Market evolution and environmental impact of BA (Source: Waide Strategic Efficiency)

BA	Job creation	Economic impact	Environmental impact (yearly after peak)	Environmental impact (2013 – 2035)
Optimal scenario	4 million new jobs from 2013 – 2034	Savings = 1.1% of EU GDP Average payback per system = 1.5 year	150 Mtoe 9% of total EU energy consumption	2100 Mtoe 5.9 Gt CO_2eq
Recommended action scenario	(no data available)	Invest = €6.2bn/year Savings = €54bn/year	89 Mtoe 5% of total EU energy consumption	1000 Mtoe 3.4 Gt CO_2eq

[8] BA is very complex to install and requires highly skilled monitoring and commissioning to ensure they keep working optimally. Compatible communication protocols between software and hardware remain a problem to ensure a qualitative installation.

IMPACT ON EXISTING AND NEW ACTORS ENTERING THE VALUE CHAIN

Figure 4: Innovation in the construction value chain – building automation and control technologies (Source: BPIE)



Innovation in the Building Automation Sector is strongly linked to innovation and change in the IT and energy sector. These sectors will strongly impact the technology evolutions of BA.

The US and Japan have strong BA markets, but most product developments for the European market will occur within Europe (mainly Germany, Switzerland, France, the UK and Italy), although many components may be sourced from outside. This is even more the case for BAT, where the technologies tend to be quite specifically geared towards the nature of the HVAC systems used.

The building automation and controls industry is quite fragmented with many players involved, but the very large players dominate the market. The top six companies account for about 37% of installed system sales. Because these conventional actors operate on closed-source software and systems, more small players are entering the market, offering simple open-source HEMS. This allows their products to be implemented more easily in larger buildings.

Some large new actors, like Google NEST and Apple, are entering the market as well focusing on the home side of the market and less on complex building systems. They often have innovative open-source platforms, allowing different applications to run. The interruptive actors could push the larger conventional market players to change their systems and business models. It might also stimulate the necessary change towards more flexible and dynamic systems.

Many of the projected newly created jobs will be for installers and energy experts for whom it will be necessary to establish competence requirements supported by accreditation and certification.

[4] These are enterprises with less than nine employees, which currently represent 94% of all enterprises active in the sector in Europe.

IMPORTANT ENABLING MEASURES TO UNLOCK THE TRANSITION

INCREASE THE RELIABILITY OF THE SAVINGS FROM BA

Today it is very precarious to organise energy performance contracting (EPC) based on a BA or to calculate return rates based on BAs expected generated energy savings. There is a lack of knowledge about international monitoring standards and because of the many components that the BA controls, it is very complex to estimate and analyse the accurate energy saving of a building. This could be overcome by the following measures:

Educating and improving the skills of the supply chain – focusing on energy engineers or maintenance companies who will operate the systems, on HVAC engineers and installers as well as on building owners.
Main actors to engage with on this topic:
- Sector federations representing the stakeholders in the building automation sector;
- National (or regional) policy makers responsible for buildings, energy and education;
- European and national certification and standards bodies;
- Formation centres;
- Research institutes.

Strengthening interoperability between different building installations like heating, ventilation units, chillers, etc. and a standardization of their communication protocol.
Main actors to engage with on this topic:
- European policy makers responsible for eco-design and energy;
- Large players in the building installation industries;
- Sector federations representing the building installation industries;
- Standards bodies;
- Research institutes.

Promoting high-quality continuous commissioning of the full systems – not just energy audits.
Main actors to engage with on this topic:
- National (or regional) public authorities responsible for buildings and energy;
- Large players in the building automation industries.

Promoting development of advanced data-analysis techniques and routes to market.
Main actors to engage with on this topic:
- National (or regional) public authorities responsible for buildings and energy;
- Large players in the building automation industries;
- Research institutes.

INCREASE THE ADOPTION OF BA

Raise awareness in the market of the value proposition.
Main actors to engage with on this topic:
- National (or regional) public authorities responsible for buildings and energy;
- Large players in the building automation industries.

Supporting and promoting (further) uptake of smart grids, demand-side management and on-site renewable energy production.
Main actors to engage with on this topic:
- European policy makers responsible for buildings and energy;
- National (or regional) policy makers responsible for buildings and energy.

Push the implementation of ISO 50001 (energy-management-system standard) in the building sector, which has the potential to stimulate the integration of energy-saving control systems.
Main actors to engage with on this topic:
- European policy makers responsible for buildings and energy;
- National (or regional) policy makers responsible for buildings and energy;
- European and national standards bodies.

Actions on both aspects are needed to create a virtuous circle, build confidence and drive demand.

BEST PRACTICES AND PILOT PROJECTS

HOMES - HOUSING AND BUILDINGS OPTIMISED FOR THE MANAGEMENT OF ENERGY AND SERVICES

- **What?** Propose operational solutions on a large scale to allow each building to achieve the best energy performance across the entire stock of European buildings, whether new or existing, residential or commercial. Five pilot cases (school, office, collective residential and two hotels) were involved in the project to test in a real situation the developed strategies (i.e. reduce needs, optimise energy supplies and involve behaviour).
- **Project outcomes?**
  At the five pilot cases, energy savings between 25% and 56% were realised. The HOMES-project concluded for the European market with the following projections:
  - Potential savings between 20-60% of a site's total energy bill;
  - Provide a return on investment between 3 and 7 years in the tertiary sector, and between 5 and 15 years in the residential sector;
  - Applied to 230 million European buildings, enabling a significant reduction of final energy demand, i.e. reduced building consumption by 40%, which is 16% of the total energy bill in Europe;
  - Would create about 600,000 direct jobs in Europe over 30 years.
- **Where?** Focus on France and the UK, with roll out opportunity for Europe.
- **Stakeholders?** 13 industry and research partners, launched by Schneider Electric.
- **Timing?** 2008-2013
- **More information?**
  http://www.eubac.org/cms/upload/newsletter/heatingandcoolingstrategy/Presentation_Homes_Project.pdf and http://www2.schneider-electric.com/documents/press-releases/en/shared/2013/02/20130213_PRG-Cloture-HOMES.pdf

IMPLEMENTING A MODEL PREDICTIVE CONTROL AT 3E'S OFFICE

- **What?** A demonstration of model predictive control on a hybrid heating system in a Brussels' office building, testing the impact on the control performance in terms of thermal comfort and energy cost. The model predictive control algorithm runs as a software service on top of the existing building energy management system (BEMS). A two-way communication infrastructure with the BEMS allows to read the monitoring data and write the optimised control set points in real-time.
- **Project outcomes?** The model predictive controller provides a similar or better thermal comfort than the reference control while reducing the energy costs by more than 30%. Zone temperature set points are followed more closely, enabling a better use of the heat pumps and an adapted hot water supply temperature.
- **Where?** Medium-sized office building in Brussels, Belgium.
- **Stakeholders?** Granted under the European ITEA2 program funded Enerficiency project, with scientific partner KU Leuven and private partners Thercon, Fixsus and Imtech.
- **Target Group?** Building owners, building asset managers, ESCOs.
- **Timing?** July 2010-July 2015.
- **More information?** http://www.3e.eu/energy-and buildings-implementing-a-model-predicting-control/

Source: 3E

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The full report is available at http://bpie.eu/publication/construction-value-chain/